Southwestern Alaska Rainbow Trout Investigations,

Kanektok River, Togiak National Wildlife Refuge, Alaska

1985-1987 Final Report

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ABSTRACT

The effects of harvest and the population status of rainbow trout
(Oncorhynchus mykiss) in the Kanektok River, Togiak National Wildlife Refuge,
Alaska, were investigated from 1985 through 1987. Rainbow trout were
collected to determine age, length and weight composition, and to estimate
population size and survival rates. A sport fishing creel survey was
conducted in 1986 and 1987 to estimate angler effort, catch, harvest and
fishing mortality of rainbow trout in a 32 km study section.

Rainbow trout ranged in otolith age from 1 to 13 years and in scale age
from 1 to 9 years. Scale ages underestimated the true age of fish in age
classes older than 5. Recruitment into the sport fishery occurs at
approximately age 4, and maturity is reached at approximately age 6. Fifty-
seven percent of the hook and line captured fish were age 6 and older.

A total of 687 rainbow trout was tagged during the study and 28% were
recaptured at least once. Tag returns indicated little in-stream movement
during the summer. The 1986 estimated population of rainbow trout vulnerable
to sport fishing within the 32 km study area was 20,815 ± 4,766. Survival
rates appeared to be constant between years and varied from 64% at age 4 to
11% at age 8 and older.

Sport fishing in the study area begins in late June and continues
through early September, with approximately 85% of the total effort occurring
in July and August. An estimated 7,692 rainbow trout were caught and 30
(0.4%) harvested in 1986. In 1987, an estimated 6,245 rainbow trout were
caught with 105 (1.7%) harvested. Guided anglers represented 77% and unguided
anglers 23% of the total effort estimated during the two year survey. Guided
float anglers showed the highest fishing success rate both years (5.6 and 5.5
rainbow trout per angler day). Guided motor boat anglers were the next most
successful with 5.0 and 2.9 rainbow trout per angler day during 1986 and 1987,
and the catch rate for unguided float anglers was 2.2 and 2.4 rainbow trout
per angler day.

Direct harvest of rainbow trout was low for all angler groups in the
study area. An estimated 1,515 fish were killed by sport fishermen during the
two year survey. Approximately 91% of these deaths were caused by delayed
hooking mortality. Assuming a 10% hooking mortality rate, a 10% increase in
sport fishing effort will result in a 0.4% increase in total mortality of fish
ages 4 through 9 and older.

Limited subsistence harvest data of rainbow trout are available. In
1988-1989, approximately 2,300 rainbow trout were harvested from the Kanektok
River. It is assumed the subsistence harvest was relatively stable from 1986
to 1989 with an annual exploitation rate of 11%.

Management recommendations include: (1) continue monitoring sport
fishing activity through Special Use Permit requirements and public use
surveys; (2) determine the subsistence harvest of rainbow trout; and (3)
reevaluate the Kanektok River rainbow trout population status in five years.

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INTRODUCTION

Sport fishing use on the Kanektok River has increased from an estimated 600 days in 1981 to over 3,300 days in 1986 (D. Fisher, U.S. Fish and Wildlife Service, personal communication). Commercial sport fishing guides have expressed concern over the status of the rainbow trout (Oncorhynchus mykiss) population, inadequate escapement data for returning Pacific salmon and increased use by the non-guided public. Residents of Quinhagak village, situated at the mouth of the Kanektok River, have raised questions of overfishing, increased traffic on the river and potential pollution of their drinking water. In 1985, the Togiak National Wildlife Refuge (Refuge) instituted a moratorium on commercially guided sport fishing activity. This action limited guides to those who had operated on the river in or prior to 1984 and their client numbers to 1984 levels, until the status of the rainbow trout population and impacts of the sport fishery can be assessed. The Alaska State Board of Fisheries reduced daily bag limits for rainbow trout in 1984 from 15 to 10 per day with no more than 2 fish over 20 inches. In 1985, an additional reduction from 10 to 2 fish per day with no size limit occurred.

Data on subsistence harvest of fish from the Kanektok River are limited. Rainbow trout are harvested from the Kanektok River by subsistence fishers primarily from the village of Quinhagak during late fall and spring. Gill nets are the principal gear employed, although hook and line, jigging, and seines are also used. From May 1988 to April 1989, 86 of the 129 Quinhagak households reported a harvest of 1,552 rainbow trout (U.S. Fish and Wildlife Service 1990). The estimated harvest for all 129 households was 2,328 rainbow trout for 1988-1989.

Little biological information had been gathered on Kanektok River rainbow trout prior to 1985. The Alaska Department of Fish and Game (Department) examined 30 rainbow trout in 1975 which ranged in scale age from 5 to 10 years and in mean fork length (FL) from 395 to 570 mm (Alt 1977). In 1983, the U.S. Fish and Wildlife Service (Service) conducted a preliminary investigation of the river and sampled 26 rainbow trout for age, weight and length data. Only 12 of the fish were successfully aged because of the high percentage of regenerated scales. These rainbow trout ranged in age from 3 to 5 years, from 330 to 609 mm (FL) and from 0.4 to 2.0 kg (C. Dlugokenski, U.S. Fish and Wildlife Service, personal communication).

Creel surveys have been conducted on the lower river by the Department since 1984, but are limited in time to chinook salmon (O. tshawytscha) and coho salmon (O. kisutch) spawning migrations. Since 1984, Togiak Refuge personnel have conducted public use surveys at Kagati Lake that provide angler profiles, estimates of river use days by rafters and daily fly-in use on the lake. Refuge issued Special Use Permits require commercial guides to report catch, harvest and effort statistics. However, there is a wide range of compliance to this requirement, ranging from excellent to poor.

The original study proposal called for a preliminary study in 1985, followed by a more intensive three year effort. It was felt that sufficient information was collected during 1985-1987 to warrant the conclusion of this study effort in 1987. This study provides information on population size, age class composition, size distribution, sport fishing effort, catch and harvest,

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survival and exploitation rates of rainbow trout in the Kanektok River, from 1985 through 1987. The study objectives were to:

1- Determine the mean length, weight and condition factor for each age class of rainbow trout vulnerable to the sport fishery in the study area.

2- Estimate annual survival of each year class of fish vulnerable to the sport fishery.

3- Estimate the population size of rainbow trout vulnerable to the sport fishery in the study area.

4- Estimate the seasonal catch and harvest of rainbow trout and other salmonids in the study area.

STUDY AREA

The Kanektok River originates at Kagati Lake and flows west approximately 150 km to Kuskokwim Bay at the village of Quinhagak (Figure 1). The total drainage is approximately 2,357 square km, and the upper 117 km of the river is within the Togiak Refuge Wilderness Area. The river is extremely braided and has many unstable and newly cut channels. Most of the riparian area has thick stands of willow (Salix sp.) and alder (Alnus sp.). Stands of cottonwood (Populus sp.) support colonies of beaver (Castor canadensis) whose impoundments and log debris provide excellent fish habitat.

The study area was chosen by the following criteria: (1) it must be within the Wilderness Area of the Refuge; (2) it must be where the majority of the rainbow trout sport fishing effort occurs; and (3) it must be suitable rainbow trout habitat. The study area for population estimates and creel survey was approximately 32 river kilometers (km) in length from km 27 (the Refuge Wilderness Area boundary) upstream to km 60. River kilometers are measured from the Kuskokwim Bay confluence upstream to Kagati Lake. The lower study section (km 27-37) is highly braided with no obvious main channel, the middle section (km 38-47) is also braided but usually contains a main channel, and the upper section (km 48-60) is less braided, often bordered by bluffs. The river is swift (averaging 1.4-1.7 m/sec) and fairly narrow, and boating is made hazardous by numerous undercut banks, newly cut channels through thick brush, and overhanging trees caused by bank erosion and beaver activity. The river has a predominantly gravel bottom for most of its course and the major tributaries are Takshilik, Nukluk, Klak, Kanuktik, and Paiyun Creeks.

METHODS

Age, Length and Weight Composition

In 1985, four float trips were conducted to obtain age, length and weight samples of rainbow trout. A Service biologist and a Department biologist spent a week in August at a guided fishing camp (located within the study area) tagging rainbow trout. Rainbow trout were captured using hook and line, fork length and weight measurements were taken, numbered Floy FD-67
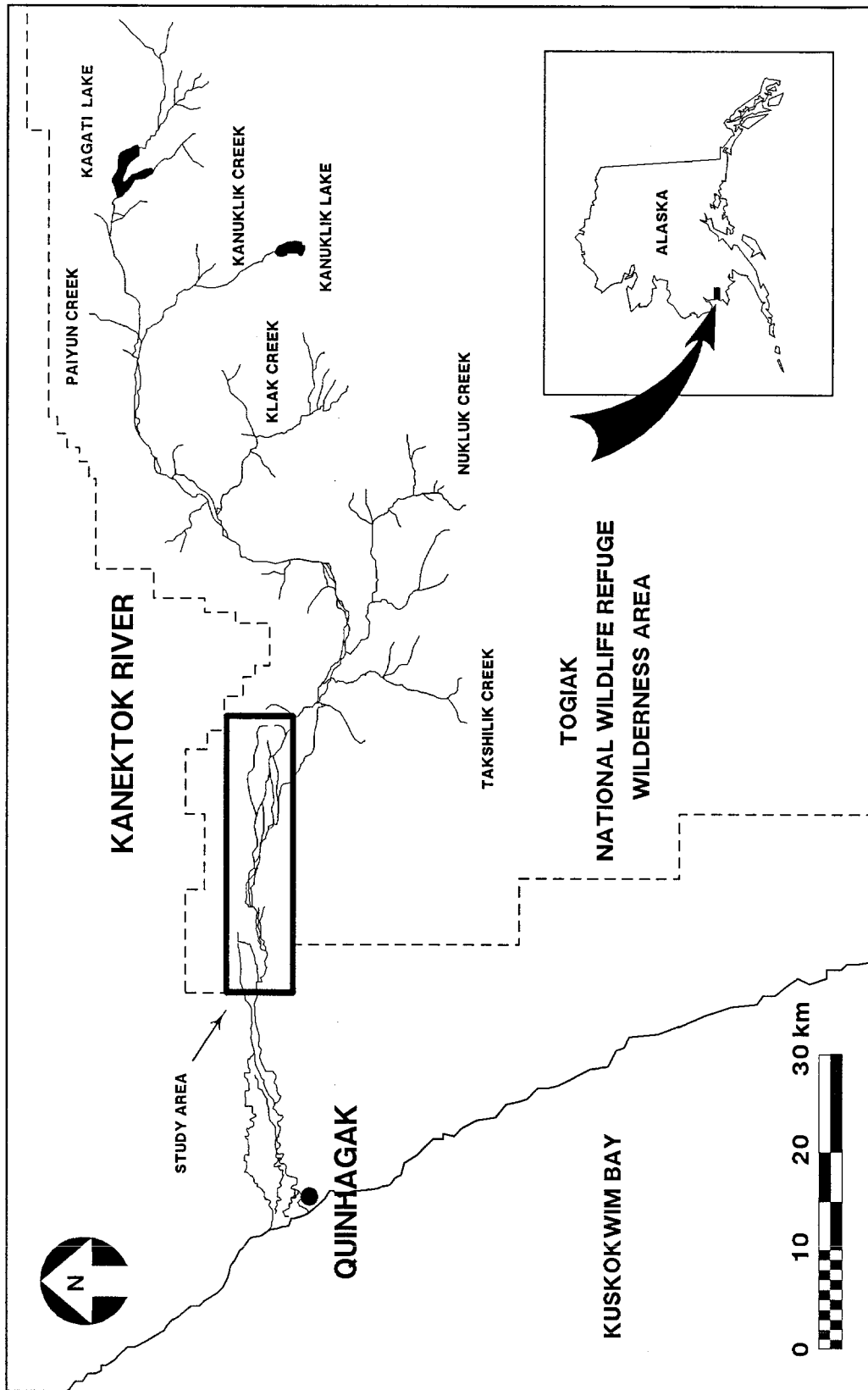
Figure 1.-Rainbow trout investigation and creel survey study area, Kanektok River, Alaska, 1985-1987.

anchor tags were inserted at the base of the dorsal fin, and scale samples were collected. Fish were designated as mature if eggs or milt were easily extruded. Sex was determined when possible by dissection. Otoliths (sagitta) were collected from mortalities. Scale and otolith samples were aged by Service staff at the Seattle National Fishery Research Center.

In 1986 and 1987, a base camp was established at km 32, and outboard jet motor boats were used to access sampling areas and conduct creel surveys. One float trip was conducted each year to sample rainbow trout from the entire river. Rainbow trout sampling procedures used in 1986 were similar to those used in 1985. In 1987, electroshocking (Smith-Root Model 15-A backpack), seining and minnow trapping were used in addition to hook and line. Log jams, small side sloughs and tributaries not usually targeted by the sport fishery were sampled more intensively in 1987 to capture juvenile rainbow trout. The tagging program was discontinued in 1987 after a small sample (44) was marked, and a larger subsample of fish was sacrificed for otolith collection. The subsample of otoliths was taken from up to 10 fish per 25 mm size group (e.g., 10 fish in range 251-275 mm (FL) were sacrificed). Recaptured, tagged fish were not sacrificed. Scales and otoliths collected in 1986 and 1987 were aged by King Salmon Fishery Assistance Office staff.

Age analysis of scale samples from 1986 and 1987 followed methodology outlined by Jearld (1983). Scales were pressed on acetate sheets, circuli impressions were highlighted by the application of a thin film of ink (Tsumura 1987) and magnified on a microfiche reader. Regenerated scales were discarded. In 1986, two independent scale readers analyzed a subsample of scales comprised of: (1) a representative of all age classes encountered after the first reading; (2) all fish with otolith samples; and (3) all sexed fish. In 1987, three independent readers analyzed the entire scale sample. Otoliths were cleared with xylene and read whole by microscopic examination (Brothers 1987). A subsample of vertebrae was collected in 1987, cleared with xylene and examined for evidence of annular markings.

Mean length and weight were calculated for each sampled age group. Fulton's condition factor (Ricker 1975) was calculated for each age group using:

$$K = W * 10^5 / L^3$$

where: K = condition factor
W = weight (g)
L = fork length (mm)

Mean lengths, weights and condition factors at age were based on scale ages to enable comparison of data between years and to utilize all aged fish. The length at age between years were compared for ages 3-8 (scale age) using t-tests at the 95% confidence level. The age class composition of the three year sample was examined for year to year variation using contingency table analysis employing the G-test of independence and chi-square statistics (Rohlf 1985). Functional regression analysis (Ricker 1975) was used to examine the relationship between length and weight.

The otolith age distribution for all scale aged fish collected during 1985-1987 (N=835) was estimated using a subsample of otolith and scale aged

fish from 1987 (N=144). The number of fish in each otolith age class was estimated using:

$$E_j = \sum_i [(S_i * A_{ij}) \div T_i]$$

where: E_j = The estimated number of otolith age j fish
S_i = The total number of scale age i fish in the scale age sample
A_{ij} = The number of otolith age j fish in the scale age i category of the otolith and scale aged sample
T_i = The total number of scale age i fish in the otolith and scale aged sample

Relative stock density (Wege and Anderson 1978) was estimated for rainbow trout based on fork length measurements. Length categories of Stock, Quality, Preferred, Memorable, and Trophy were adapted from Gabelhouse (1984). Length ranges for each category were selected to reflect the non-anadromous and non-lacustrine strategy, and consequently smaller size range, of resident stream dwelling Alaskan rainbow trout as follows: Stock <299 mm; Quality 300-399 mm; Preferred 400-499 mm; Memorable 500-599 mm; Trophy >600 mm. The length categories assigned by Gabelhouse (1984) are based on world record lengths and include anadromous steelhead trout. Size categories selected for our estimates of relative stock density were based on angler and guide interviews, length frequency data, and literature review.

Survival Estimates

Scale ages were used for survival estimates in order to compare rates between years 1985 to 1987. The estimated otolith age distribution for the 1987 sample was used to assess the possible effects of scale ageing error on age distribution and age-based mortality rate estimates. However, as otolith collection was restricted to one year (1987) and from only 144 fish, the adjustment was not applied to the overall survival estimates used for contingency table analysis of year to year variation in age class composition.

Catch curve analysis was used to estimate annual survival rates using age class frequency distribution data (scale age) and assumes constant year class strength, constant survival rate and equal probability of capture (Robson and Chapman 1961). Due to sample size and scale ageing limitations, age 8 and older fish were combined into one age group for this analysis. The assumption of equal probability of capture was tested by comparing annual survival rates to Heincke's survival estimate. When a discrepancy arose between these results, a chi-square analysis was used to test the significance of observed age group deficiencies (Robson and Chapman 1961).

Population Estimates

A modified Petersen mark-recapture estimator was selected to estimate the population of rainbow trout vulnerable to the sport fishery in the study area. Estimates were calculated for both the 1985 and 1986 seasons.

Population estimates, the approximate variance of the estimates, and adequacy of sample size were calculated (Everhart and Youngs 1981).

All reported captures and recaptures from both the sport fishery and staff personnel were pooled for the estimates. For the estimate, fish tagged after 14 July, the initial tagging period, or tagged in 1985 were eliminated. Coefficients of variation and probability of capture (White et al. 1982) were used to determine precision and reliability of model selection. The following assumptions were made: (1) there was geographic and demographic closure; (2) the total number of marked and unmarked captured fish was reported accurately; (3) marked fish were randomly mixed throughout the population; (4) fishing effort was proportional to the density of marked fish; (5) there was no tag loss; and (6) marked and unmarked fish were equally vulnerable to the fishery.

Effort, Catch and Harvest Estimates

The lower river (below the Wilderness Area) creel surveys were conducted by Department personnel. In 1986, the lower river survey was conducted from 20 June through 4 September and covered the lower 32 km. This survey was primarily conducted to collect creel data on chinook and coho salmon. In 1987, the lower river survey was conducted from 20 June through 24 July and targeted the chinook salmon sport fishery in the lower 20 km. Department creel survey effort estimates were recorded in hours and converted to angler days by dividing the number of hours recorded by 7.6, the reported average number of hours spent fishing per day (Minard 1987).

The upper river creel surveys were conducted in the study area by Service personnel, and included both individual angler interviews and voluntary reports by sport fishing guides. Interviews were conducted over an 11 week period (30 June through 14 September) in 1986 and a 12 week period in 1987 (20 June through 11 September). Creel survey data were stratified by week and by user group as follows:

(1) Guided motor boat anglers and guides were interviewed at the end of the fishing day at two camps located within the study area. In 1986, four of the usual six fishing days per week were randomly sampled, and these data were then expanded to estimate the full fishing week. In 1987, daily effort and catch statistics were reported by the guides, and no expansion was necessary.

(2) Guided float angler effort and catch statistics were provided by the guides as a requirement of the Refuge Special Use Permits. Since all permittees did not provide catch statistics, catch rates for non-reporting guides were assumed to be equal to reporting guides.

(3) Unguided float angler effort was estimated by multiplying the number of people reported by Refuge personnel stationed at Kagati Lake by a three day expansion factor (based on Service float trip records) to estimate the time spent within the study area. This method assumes equal effort and catch for non-interviewed groups and does not account for non-fishing rafters or incomplete trips.

Data collected from all groups included: (1) number of days fished in the study area; (2) number and species of fish caught and harvested;

(3) number of tagged fish caught and tag numbers; and (4) capture location of tagged fish if known. The following assumptions were made: (1) only three angler groups used the study area; (2) the count of the angler population based on Special Use Permit reports and Refuge personnel reports from Kagati Lake was accurate; (3) voluntary reporting was accurate; and (4) catch and harvest rates were similar for reporting and non-reporting anglers within the same angler groups, during the same time periods.

Effort, catch, and harvest statistics were used to estimate fishing mortality. Estimates of fishing mortality per unit effort were calculated for each angler group using a 10% hooking mortality rate (Horton and Wilson-Jacobs 1985):

$$F_i = [H_i + (C_i - H_i) * 0.10] / E_i$$

where: F_i = fishing mortality per unit effort
H_i = harvest
C_i = catch
0.10 = 10% hooking mortality
E_i = effort in angler days per user group i

Total mortality rates (natural plus fishing mortality) from the estimated otolith age distribution were calculated for ages 4-9 years. Because of small sample size, all fish of age 9 and older were combined into the age 9 category. Then, using the average fishing mortality per unit effort for all angler groups combined, total mortality rates were calculated for fishing efforts of 20%, 50%, and 100% over 1986 levels.

Assumptions for this analysis are: (1) natural mortality rate is presently at equilibrium (i.e., recruitment = spawner loss); (2) additional fishing mortality is additive; (3) catch, harvest, and fishing mortality rates will remain constant; and (4) hooking mortality rate is constant for all age groups of rainbow trout in the fishery and for all angler groups.

RESULTS

Age, Length and Weight Composition

A total of 1,180 rainbow trout was examined for age, length and weight data. Of these, 840 (78%) were successfully aged by one or more methods (scales, otoliths or both). Twenty-two percent of the scale samples and less than 2% of the otolith samples were unreadable. Annual marks were not apparent on vertebrae. Rainbow trout ranged in otolith age from 1 to 13 years and in scale age from 1 to 9 years. Fork length ranged from 80-628 mm, weight ranged from 0.01-3.00 kg and condition factor ranged from 0.80-1.86 (Tables 1-3). Over 75% of the hook and line captured fish were 350-525 mm FL (Figure 2). The length weight regression for each year (Figure 3) and all years combined (Figure 4) were calculated. The slope of each year's regression equation were compared; 1986 was significantly different from both 1985 ($P<0.01$) and 1987 ($P<0.005$), while 1985 was not significantly different from 1987 ($P>0.50$).

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Table 1.-Mean length (L) in mm, sample size (N) and standard deviation (SD) of rainbow trout, by scale age, Kanektok River, Alaska, 1985-1987.

Year						Scale Age				
		1	2	3	4	5	6	7	8	9
1985	L			335	342	391	450	499	538	
	N			2	23	32	43	27	11	
	SD			23	31	46	33	52	46	
1986	L		296	330	359	403	447	483	523	595
	N		3	6	49	91	141	64	20	3
	SD		36	28	39	40	35	34	30	25
1987	L	80	169	218	312	392	427	473	488	554
	N	1	1	30	46	60	100	69	13	5
	SD	-	-	29	37	50	40	49	41	59

Table 2.-Mean weight (W) in kg, sample size (N) and standard deviation (SD) of rainbow trout, by scale age, Kanektok River, Alaska, 1985-1987.

Year						Scale Age				
		1	2	3	4	5	6	7	8	9
1985	W			0.34	0.51	0.76	1.14	1.52	1.93	
	N			2	19	26	40	23	11	
	SD			0.13	0.14	0.24	0.23	0.52	0.42	
1986	W		0.28	0.58	0.59	0.60	1.01	1.27	1.49	2.05
	N		3	6	47	84	135	58	19	3
	SD		0.02	0.18	0.18	0.24	0.25	0.29	0.30	0.57
1987	W	0.01	0.08	0.13	0.37	0.71	0.91	1.23	1.32	1.89
	N	1	1	30	45	60	100	69	13	5
	SD	-	-	0.08	0.15	0.26	0.30	0.41	0.53	0.65

Table 3.-Fulton's condition factor (K), sample size (N) and standard deviation (SD) of rainbow trout, by scale age, Kanektok River, Alaska, 1985-1987.

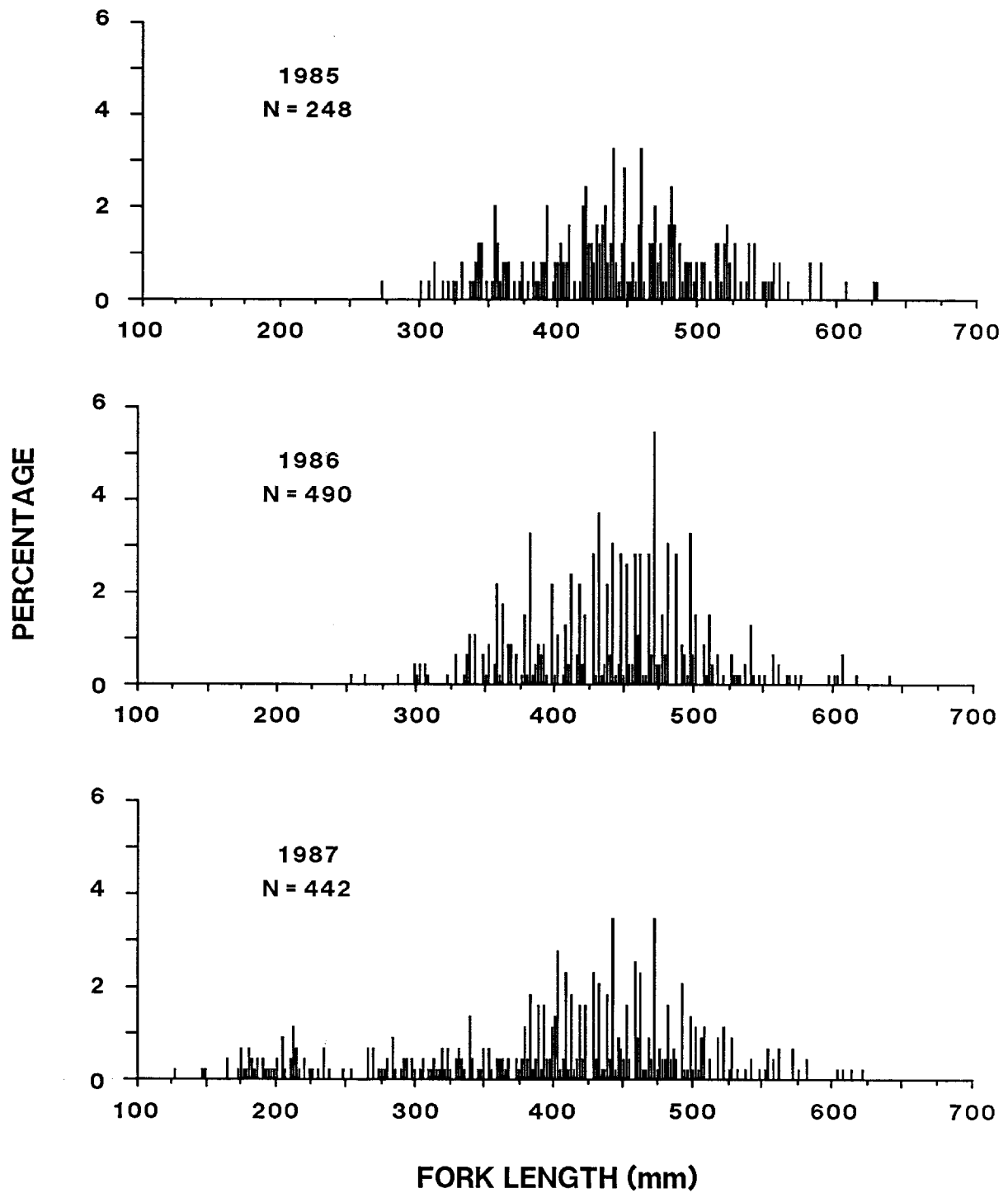| Year						Scale Age				
		1	2	3	4	5	6	7	8	9
1985	K			0.89	1.28	1.21	1.21	1.22	1.22	
	N			2	19	26	40	23	11	
	SD			0.15	0.29	0.17	0.12	0.11	0.09	
1986	K		1.16	1.48	1.24	1.13	1.12	1.10	0.98	0.95
	N		3	6	47	84	135	58	19	3
	SD		0.48	0.39	0.31	0.33	0.18	0.22	0.26	0.16
1987	K	1.22	1.66	1.16	1.18	1.15	1.15	1.14	1.10	1.07
	N	1	1	30	45	60	100	69	13	5
	SD	-	-	0.12	0.33	0.23	0.33	0.18	0.30	0.15

Figure 2.-Length frequency of rainbow trout (2 mm increments), Kanektok River, Alaska, 1985-1987.
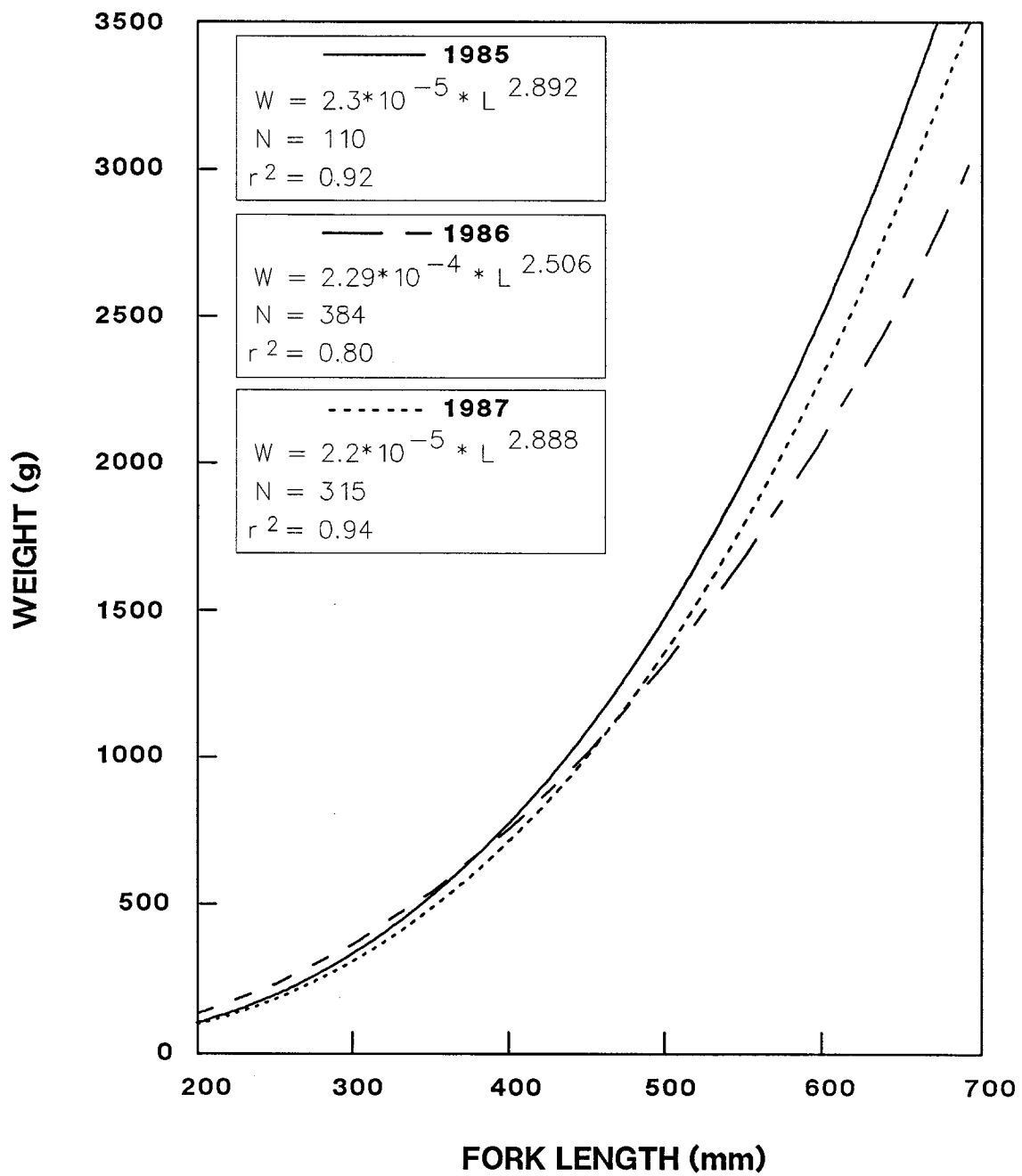
Figure 3.-Rainbow trout length-weight relationships, 1985-1987, Kanektok River, Alaska.
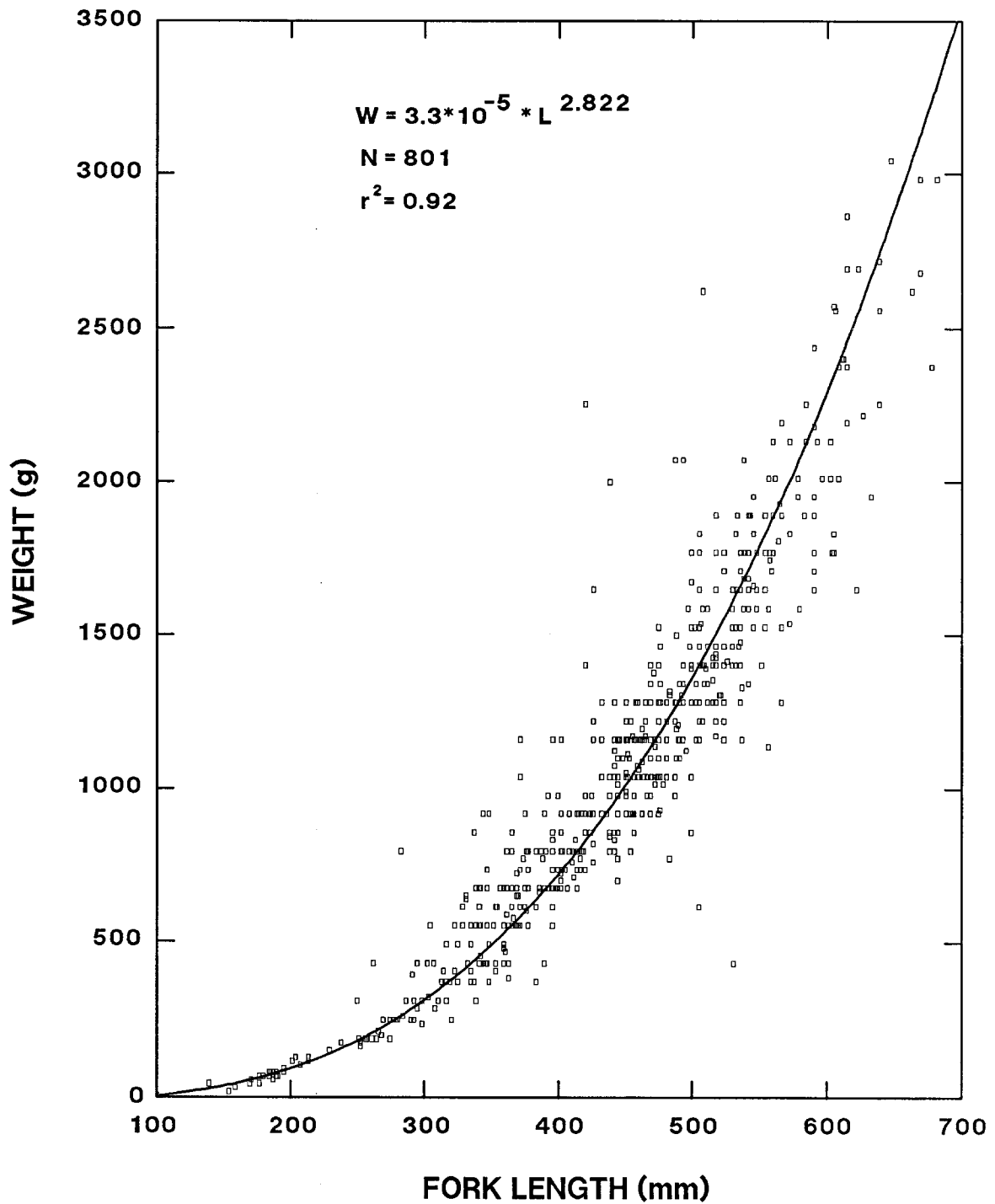
Figure 4.-Combined length-weight relationship for rainbow trout sampled during 1985-1987, Kanektok River, Alaska.

Comparisons of otolith and scale age data, from the sample of fish with both structures sampled, indicate that scale ages underestimate the true age of fish greater than age 5 (Figure 5). The estimated otolith age distribution indicates that scale ageing results in a biased age composition (Figure 6). The mean age from the scale sample was age 5, whereas the estimated otolith sample yielded a mean age of 6 years.

Recruitment into the sport fishery begins at approximately 300 mm FL and approximately age 4. By age 6, rainbow trout were fully recruited into the sport fishery. Sexual maturity is reached at approximately age 6, based on a sample of 11 fish with field comments indicating adult fish either 'ripe' or 'spent'. Eight of these were successfully aged at 6 to 8 years. Fifty-seven percent of the rainbow trout sampled were scale aged at age 6 or greater.

For 3-8 year old fish (scale age), mean length at age did not differ significantly ($P>0.50$) between 1985 and 1986. Significant differences were found between 1985 and 1987; all ages, except 5 year olds, were significantly smaller in 1987 ($P<0.04$). Also, significant differences were found between 1986 and 1987; all ages, except 5 and 7 year olds, were significantly smaller in 1987 ($P<0.04$).

Contingency table analysis of age class composition data from scale aged rainbow trout indicated that the frequency distributions did not change significantly ($P>0.50$) between the 1985, 1986, and 1987 samples (i.e., the number of fish in each age class was independent of the year of capture).

Ten rainbow trout were classed in the 'Trophy' category (> 600 mm) and the majority of sampled fish (55%) were in the 'Preferred' category. A higher percentage of 'Stock' sized fish was reported for 1987 due to the increased effort to capture smaller fish (Figure 7).

Survival Estimates

Annual survival rates of scale aged rainbow trout were constant between years but varied between age classes (Table 4). Chi-square analysis of age class frequency indicates significant ($P<0.05$) deficiencies in numbers of fish in age classes as old as six. As no fish were scale aged over age 9, there was little information about the true annual survival rate of the oldest age classes (9-13) and survival estimates may be biased. Using the estimated otolith aged distribution, survival rates increased suggesting that the scale ageing error may overestimate mortality (Figure 8). The estimated otolith aged sample shifts the ages of greatest mortality rate from ages 5-7 to ages 7-9.

Population Estimates

A total of 687 fish was tagged during the three year study period (Table 5). Of these, 191 (28%) were recaptured in the sport fishery and by Service personnel. Twelve multiple recaptures were reported. One fish was recaptured five times, two fish were recaptured three times, and nine fish were recaptured twice. The location of capture was identified for 79 of the 1986 tag returns and 76% of these were recaptured within 1.6 km of their original tagging location.
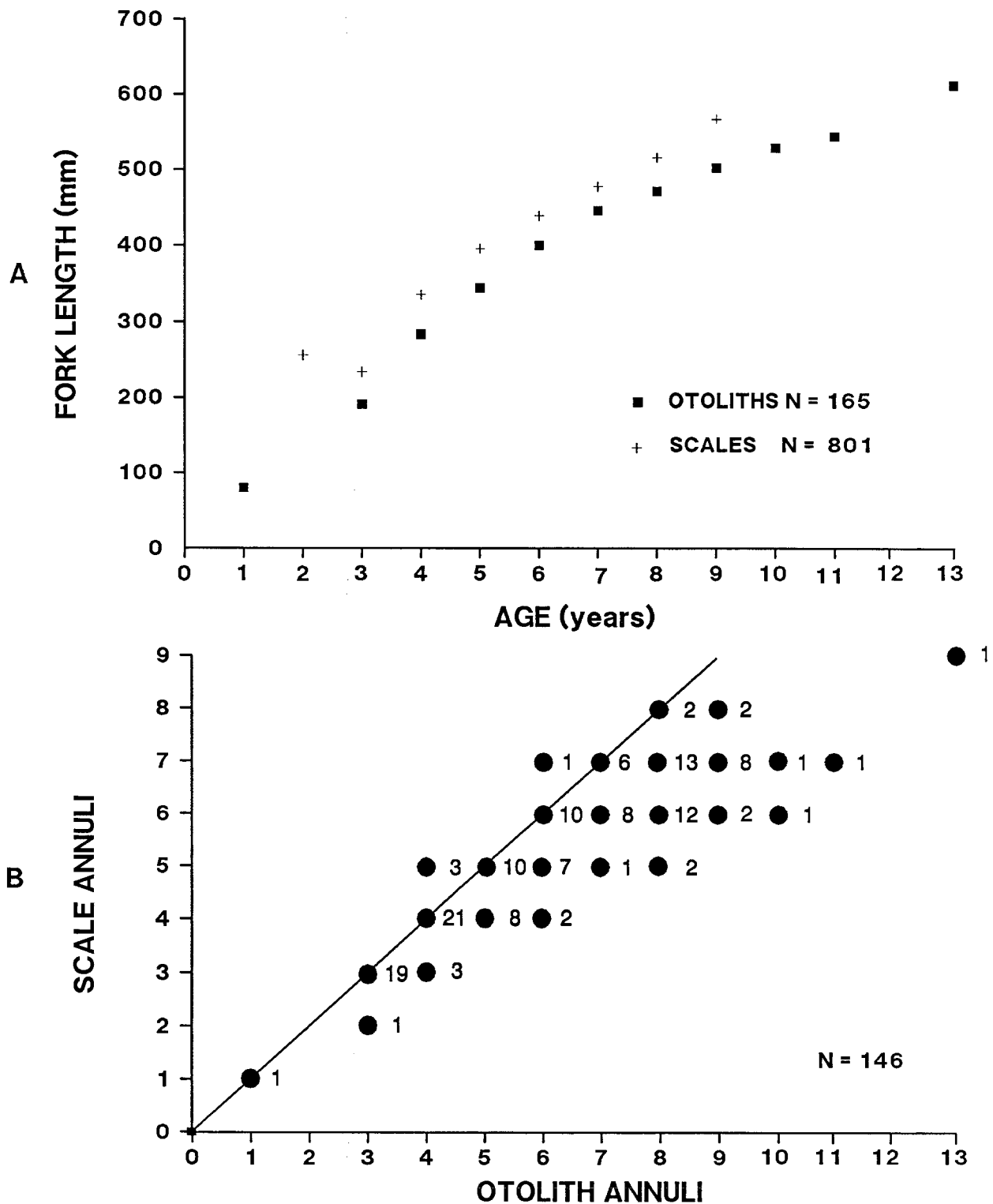
Figure 5.-(A) Relationship between mean length at age for otolith and scale ages. (B) Relationship between otolith and scale ages; line represents a 1:1 relationship between the axes. Rainbow trout data from Kanektok River, Alaska, 1985-1987. Based on fish with both otoliths and readable scales.
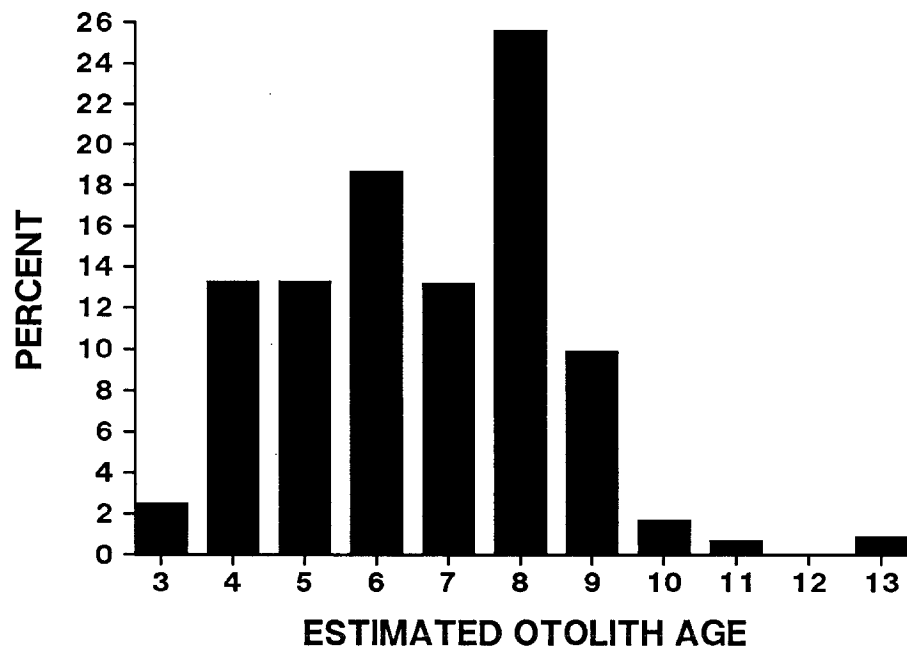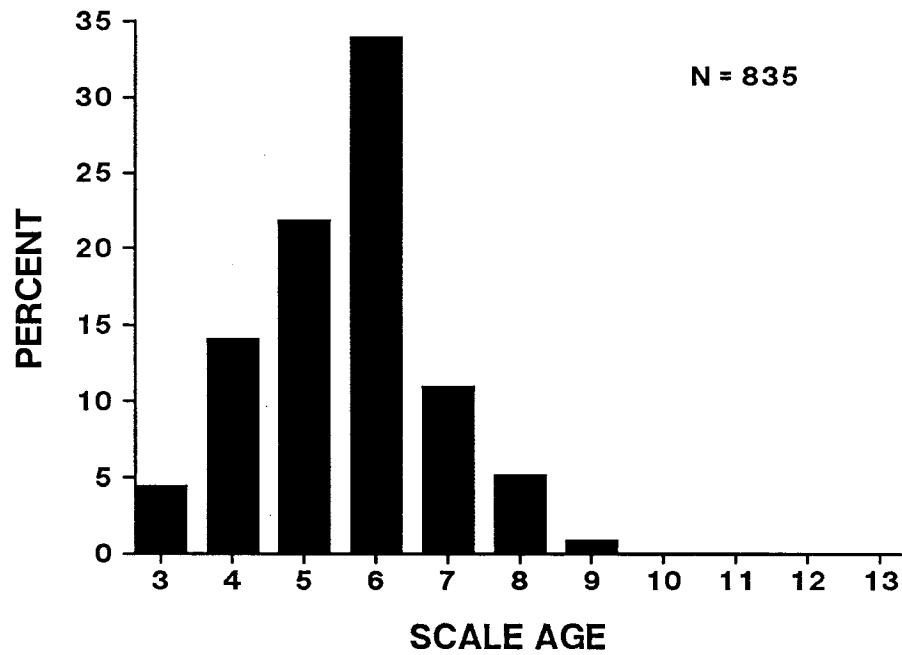
Figure 6.-Effects of estimating otolith age from scale age on age class distribution of Kanektok River, Alaska, rainbow trout.
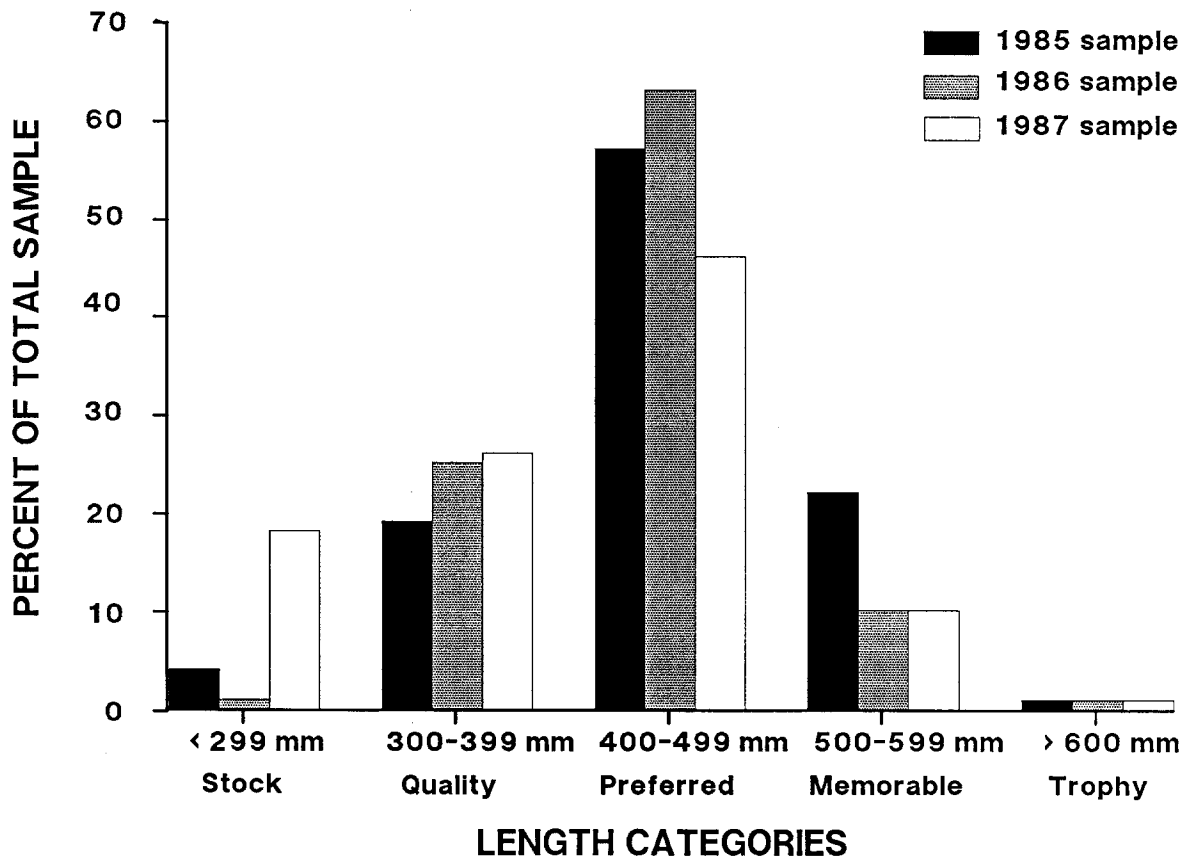
Figure 7.-Rainbow trout relative stock density, Kanektok River, Alaska, 1985-1987.

Table 4.-Estimated annual survival rate (S) by age class, 95% confidence intervals (CI), Heincke's estimate of survival (H) and chi-square statistic (X^2), Kanektok River, Alaska, rainbow trout sampled from 1985-1987. Critical X^2 value = 3.8, P = 0.05.

	Year											
	1985				1986				1987			
Age	S	CI	H	X^2	S	CI	H	X^2	S	CI	H	X^2
4	0.64	0.05	0.83	33.4	0.64	0.03	0.86	129.5	0.65	0.10	0.84	74.2
5	0.54	0.06	0.72	27.5	0.52	0.04	0.72	105.2	0.54	0.04	0.76	84.6
6	0.38	0.08	0.47	7.4	0.33	0.05	0.39	8.5	0.37	0.05	0.47	0.2
7	0.15	0.08	0.58	710.6	0.23	0.07	0.27	3.2	0.21	0.08	0.20	0.1
8					0.11	0.12	0.12	0.2	0.22	0.18	0.28	1.3

Table 5.-Number (percent) of rainbow trout tagged, released and recaptured, Kanektok River, Alaska, 1985-1987.

Year tagged	Number tagged/released	Number recaptured		
		1985	1986	1987
1985	236	2 (1)	23 (9)	7 (3)
1986	407		110 (27)	41 (10)
1987	44			8 (18)

Figure 8.-Mortality rates of age 4-9 rainbow trout, calculated from scale and otolith ages.

The modified Petersen population estimates for 1985 and 1986 produced point estimates of 17,159 and 20,815 rainbow trout, respectively. The measures of reliability differ because of sample size (Table 6). The density of catchable size rainbow trout (>300 mm) within the study area was estimated at 536 and 631 rainbow trout per km in 1985 and 1986, respectively.

Effort, Catch and Harvest Estimates

The Department estimate of angler days for the lower river (below the Wilderness Area) was 1,566 in 1986 (Table 7). The rainbow trout catch was estimated at 2,376 fish (2% harvested) (Minard 1987). In 1987, the creel census was terminated on 24 July and numbers comparable to 1986 could not be estimated.

Sport fishing activity in the upper river study area began in late June and continued through early September. Approximately 86% of the total 1986 effort and 85% of the 1987 effort occurred in July and August.

Estimated angler days within the study area were 1,753 (1986) and 1,653 (1987). Guided motor boat anglers accounted for an estimated 40% and 47% of the total effort for 1986 and 1987, respectively. Guided float anglers represented 31% (1986) and 36% (1987) of the effort, and unguided float anglers comprised the remaining 29% (1986) and 17% (1987) (Figure 9).

An estimated 7,692 rainbow trout were caught in the study area and 30 (0.4%) were harvested in 1986. In 1987, an estimated 6,245 rainbow trout were caught with 105 (1.7%) harvested. Guided motor boat anglers caught 49% and 36%, guided float anglers caught 36% and 53%, and unguided float anglers caught the remaining 15% and 11% of the total estimated catch for 1986 and 1987, respectively (Figure 9).

Rainbow trout catch per unit effort varied over the study periods and by angler group, and harvest per unit effort was low for all angler groups in the study area (Figures 10 and 11). For all three user groups, weekly harvest per unit effort averaged less than 0.1 fish per angler day, except for one week in 1986 and three weeks in 1987. The highest harvest rates were for chinook, coho and sockeye salmon ($\underline{O}$. $\underline{nerka}$) (Appendix A).

Seasonal catch per unit effort (all groups combined) in the study area during 1986 and 1987, was 4.4 rainbow trout per angler day (0.58 per hour) and 3.8 per angler day (0.50 per hour). The catch per unit effort for the lower river was 1.5 rainbow trout per angler day (0.20 per hour) in 1986. Pooled catch per unit effort for both river sections in 1986 was 3.0 rainbow trout per angler day (0.40 per hour).

Annual fishing mortality in the study area was estimated at 796 rainbow trout in 1986 and 719 fish in 1987. Delayed mortality (hooking mortality) accounted for 96% and 85% of the total estimated fishing mortality from 1986 and 1987, respectively. The remaining mortality was the result of direct harvest. Creel statistics (Department and Service) for the lower 60 km were pooled to estimate a sport fishing loss of 1,077 rainbow trout in 1986. Fishing mortality per unit effort varied by user group and ranged from 0.24 rainbow trout per angler day to 0.58 per angler day (Table 7).

Table 6.-Population estimates (N), 95% confidence intervals (CI), density (fish/km) (D), coefficient of variation of the estimates (CV(N)), number of fish marked (n_1), captured (n_2) and recaptured (m_2), and the probability of capture (P) for rainbow trout (>300mm), Kanektok River, Alaska, study area 1985 and 1986.

Year	N	CI	D	CV(N)	n_1	n_2	m_2	P
1985	17,159 $\pm$ 19,064		536	0.50	59	857	2	0.002
1986	20,815 $\pm$ 4,766		631	0.12	365	4037	70	0.020

Table 7.-Estimates of fishing effort (angler-days), rainbow trout catch and harvest (number of fish), estimated 10% catch and release mortality (10% M), total fishing mortality (M) and estimated fishing mortality per unit effort (FMPUE) for each sampled user group for the Kanektok River study area, Alaska, 1986 and 1987.

| | 1986 | | | | | |
| | User group[a] | | | Upper[b] | Lower[c] | Grand |
	GF	GMB	UGF	river	river	total
Effort	543	709	501	1,753	1,566	3,319
Catch	3,067	3,536	1,089	7,692	2,376	10,068
Harvest	11	7	12	30	55	85
Released	3,056	3,529	1,077	7,662	2,321	9,983
10% M	306	353	108	766	232	998
M	317	360	120	796	287	1,083
FMPUE	0.58	0.51	0.24	0.45	0.18	0.33

| | 1987 | | | | | |
| | User group | | | Upper | Lower[d] | Grand |
	GF	GMB	UGF	river	river	total
Effort	601	770	282	1,653	-	-
Catch	3,324	2,254	667	6,245	-	-
Harvest	0	27	78	105	-	-
Released	3,324	2,227	589	6,140	-	-
10% M	332	223	59	614	-	-
M	332	250	137	719	-	-
FMPUE	0.55	0.32	0.48	0.43	-	-

[a] GF = guided float anglers
GMB = guided motor boat anglers
UGF = unguided float anglers
[b] Upper river = 32 km study area
[c] Lower river = mouth-wilderness boundary creel data (Minard 1987).
[d] Lower river creel survey conducted 20 June - 24 July and is not comparable to upper river survey.
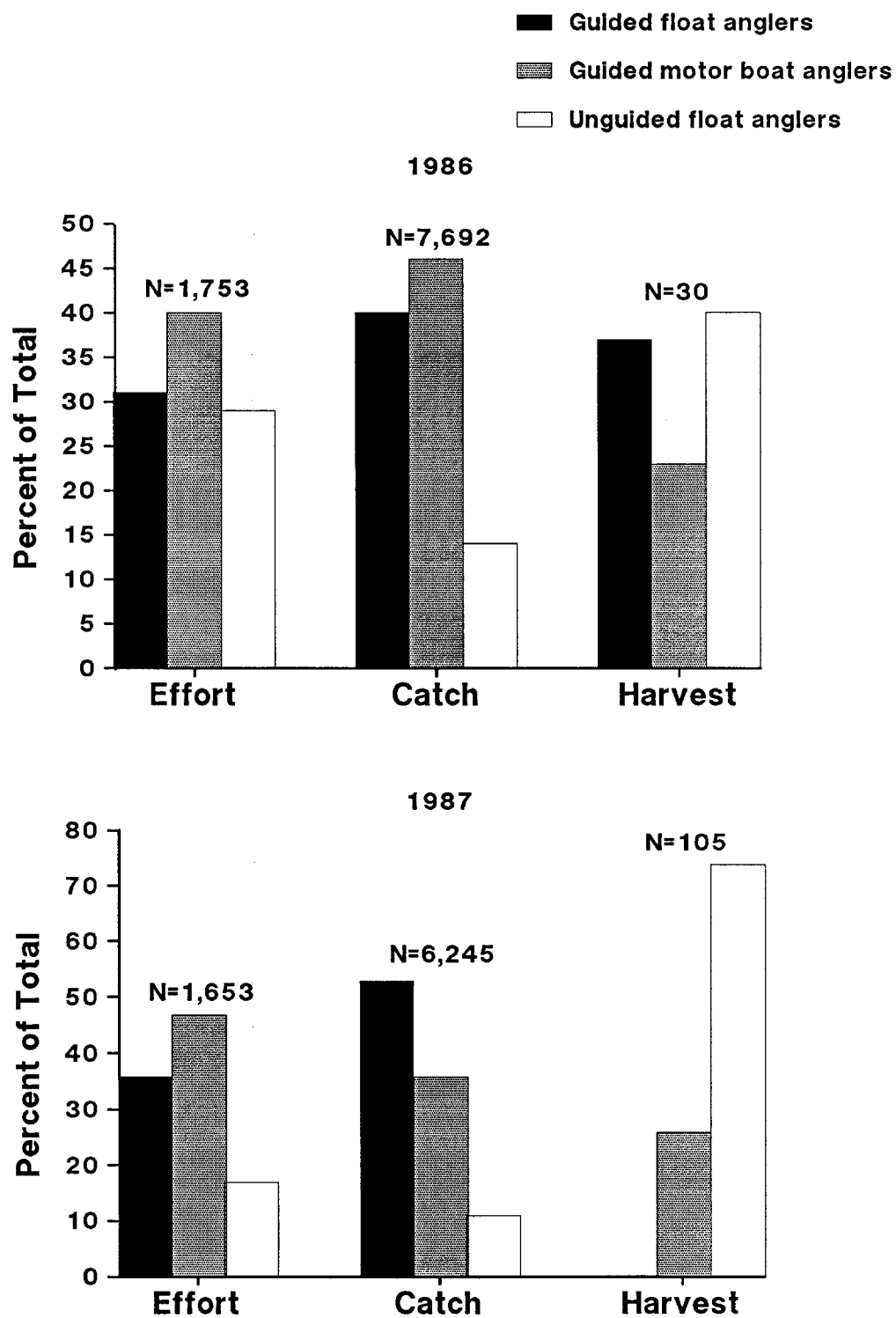
Figure 9.-Percentage of estimated sport fishing effort (angler days), rainbow trout catch and harvest (number of fish) per sampled user group, Kanektok River, Alaska, 1986 and 1987.
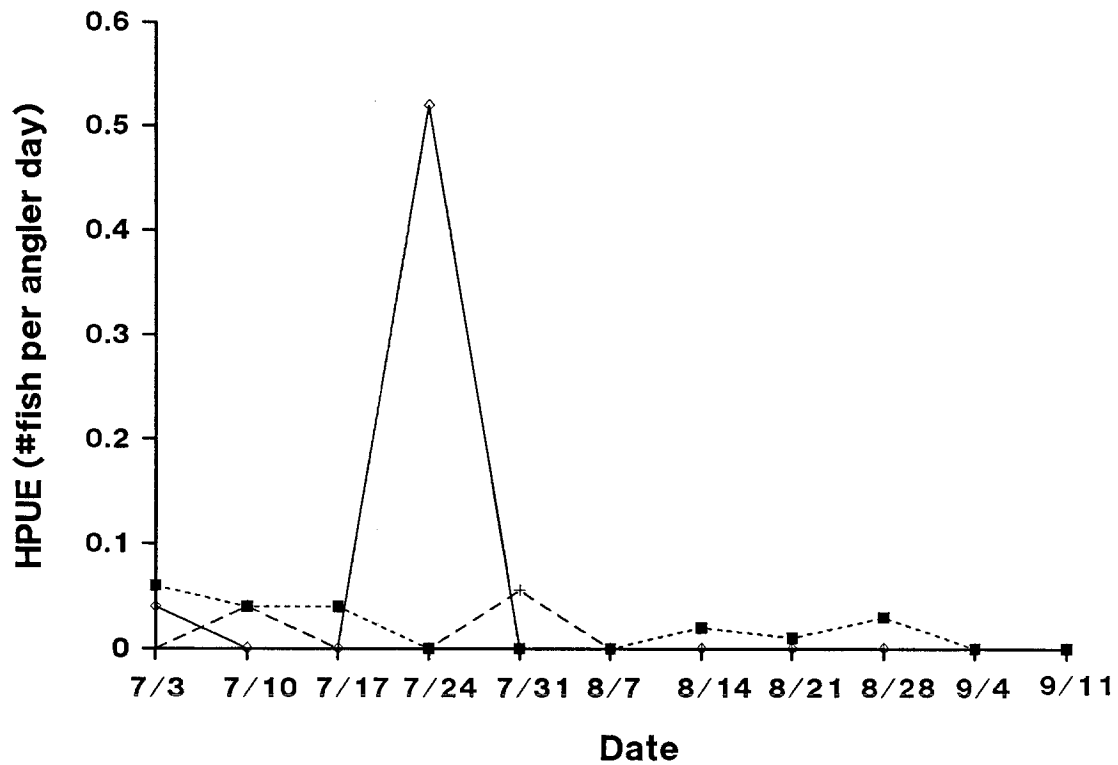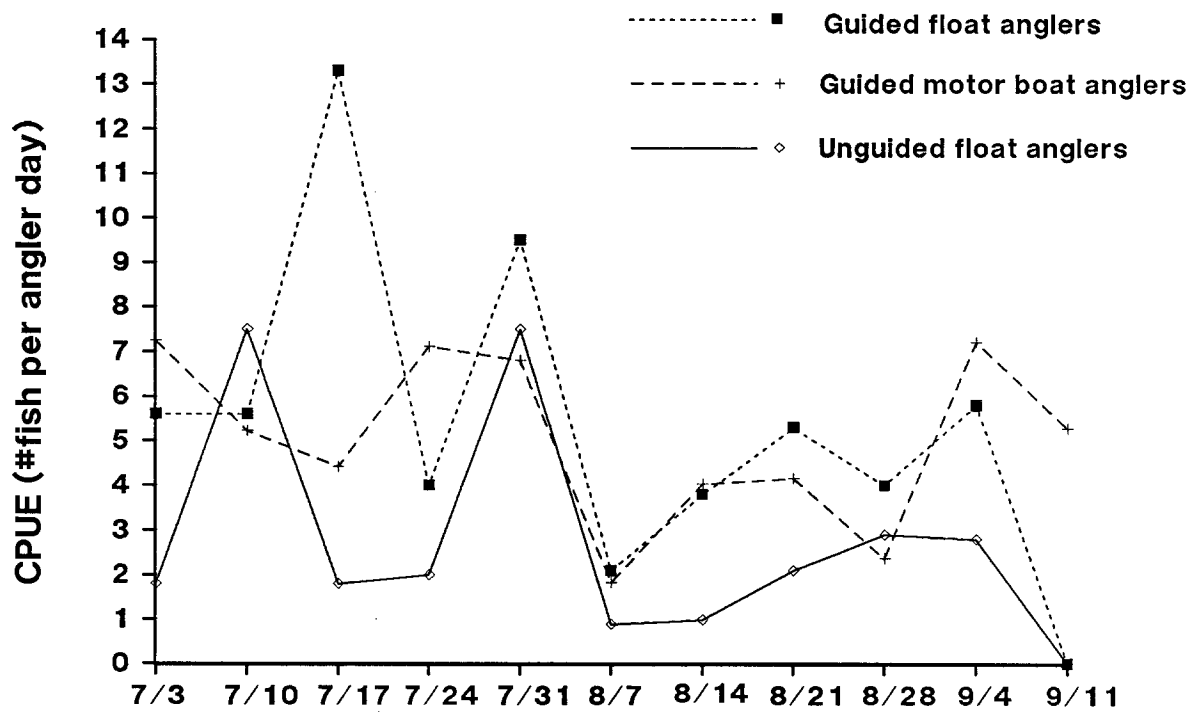
Figure 10.-Estimated weekly rainbow trout catch per unit effort (CPUE) and harvest per unit effort (HPUE) by user group, Kanektok River, Alaska, 1986.
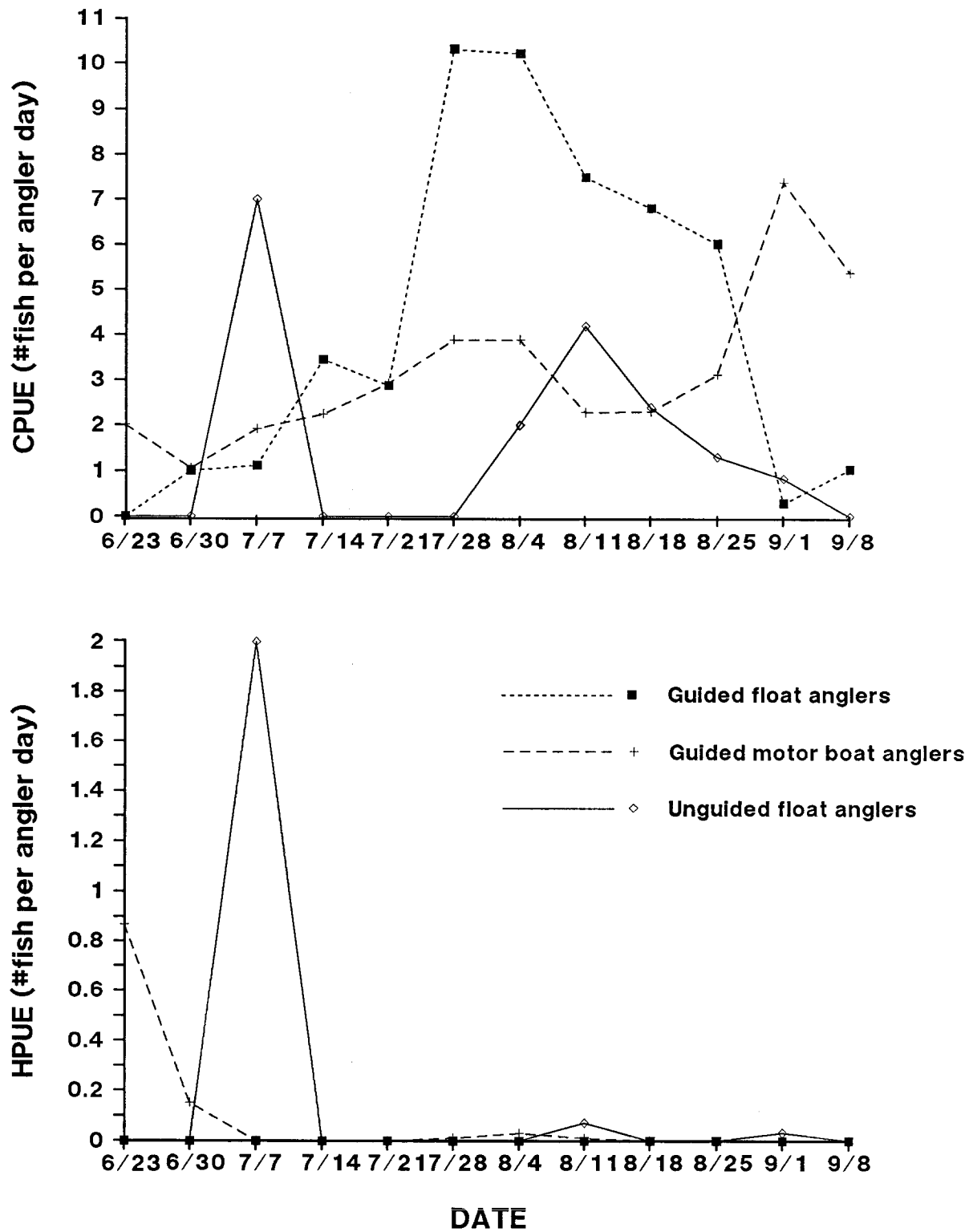
Figure 11.-Estimated weekly rainbow trout catch per unit effort (CPUE) and harvest per unit effort (HPUE) by user group, Kanektok River, Alaska, 1987.

Creel survey and population estimates indicate a present fishing mortality exploitation rate of 4% per year. Assuming catch and harvest rates remain constant and a 10% hooking mortality, every 10% increase in fishing effort results in a 0.4% increase in total mortality for age groups 4 to 9 and older (Figure 12).

DISCUSSION

Age, Length and Weight Composition

The population analyses for this study are based on scale ages because: (1) otolith samples were collected by size range and do not truly represent the population; (2) most studies of rainbow trout are based on scale age; and (3) comparison of data between years necessitates the use of scale aged fish. Ageing technique validation was not attempted for this study.

Scale age analyses for slow growing populations of rainbow trout are subject to error because: (1) slow growth produces tightly spaced circuli with indistinct annuli; (2) scale margin resorption occurs at spawning often making outer scale annuli unrecognizable; and (3) annuli often fail to form during the first winter (Lentsch and Griffith 1987). Otoliths seem to be resorbed less readily and are considered to provide more reliable age estimates, particularly for older fish (Carlander 1987). Scales may be reliable up to maturity, as indicated by close agreement between otolith and scale samples of age classes up to approximately 5 years for Kanektok River rainbow trout.

Management implications of ageing error include: (1) consistent underageing of fish; (2) maximum ages are not determined; (3) age class estimates are biased toward younger ages with accumulation of estimates in the vicinity of the age where the scale technique breaks down; (4) mortality estimates may be biased; (5) size at age data are biased upwards; (6) age at maturity and number of reproductions may be misinterpreted; and (7) overexploitation of larger, older fish may not be apparent due to the combination of older age classes. Estimating otolith ages from scale age data may reduce these errors or at least make researchers aware of their bias.

The otolith sample from 1987 indicated a greater range of age classes and a greater maximum age (13) than previously reported. The maximum age for non-anadromous rainbow trout reported by Carlander (1969) was 11 for Eagle Lake, California. Alt (1975) reported a 12 year old rainbow trout from the Goodnews River, Alaska, and a 10 year old fish from the Kanektok River (Alt 1977). The Alaska samples were aged by scale analysis.

Increased effort in 1987 to sample juvenile rainbow trout for length at age and first year annulus formation data yielded very poor results. Trapping and electroshocking in locations throughout the study area produced only one yearling rainbow trout. The increased sample of age 3 fish was the result of concentrated fishing effort on log jams and side channels. Failure to locate juvenile (less than 3 years) rainbow trout may be attributed to the large populations of juvenile Dolly Varden char (Salvelinus malma), chinook, and coho salmon present in the system. The rainbow trout appear to be a small proportion of this mixed species community.
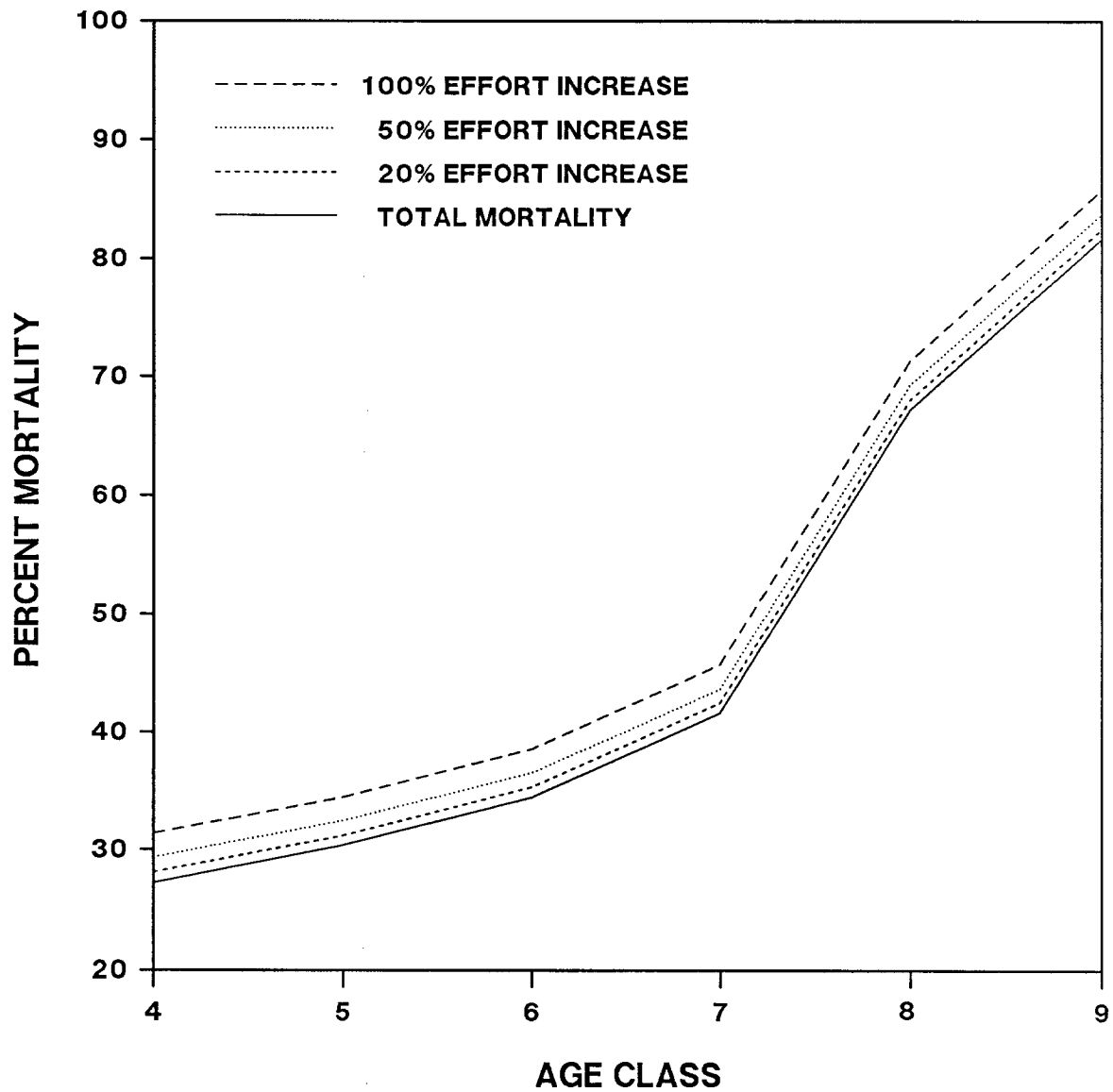
Figure 12.-Effects of incremental increases of sport fishing effort on the mortality of rainbow trout. Total mortality from estimated otolith age rainbow trout, Kanektok River, Alaska.

Condition factors of Kanektok River rainbow trout appear to decrease slightly throughout the lifespan of the fish. From a comparison of length and weight regressions between years, the condition (slope of the regression equation) of rainbow trout in 1986 was less than 1985 or 1987. It is unclear why the fishes' condition decreased for one year, but may be related to environmental factors (e.g., water temperature, flow, or water clarity) or the abundance of food resources.

A decrease in mean length at age from 1985 to 1987 was evident for most age classes. The decrease was noted for both large and small rainbow trout. If the decrease in mean length were evident only for larger, fully vulnerable age classes, then fishery impacts would be suspect. Environmental fluctuations (e.g., water temperature, stream flow) could cause this decrease in size.

Length frequency and length categorization systems such as relative stock density can be used to compare rainbow trout populations between years, areas and management strategies, and to set management objectives for fish stocks. The assignment of minimum lengths for each category, and the determination of the number of categories to be used for Alaskan rainbow trout stocks should reflect the varying life strategies of these stocks. Anadromous, lake, and stream resident populations may have very different growth, recruitment and mortality functions, and relative stock density designations should reflect these differences.

A sample of 107 Goodnews River, Alaska, rainbow trout collected during 1984 and 1985 were assigned to relative stock density categories (A. Decicco, Alaska Department of Fish and Game, and C. Dlugokenski, U.S. Fish and Wildlife Service, personal communication). The Goodnews River sample had a higher percentage of fish in the 'Memorable' category than the Kanektok River (51% and 13%, respectively). Approximately 38% of the Goodnews River sample were classed as Preferred, whereas an overall average of 55% of Kanektok River rainbow trout were within this category. These differing proportions may indicate that Goodnews River fish are genetically larger, have a different population structure, or that the Kanektok River rainbow trout population has been impacted by sport fishing or density factors.

Survival Estimates

Comparison of age class composition from the 1985-1987 samples indicates that the rainbow trout population structure was probably stable. There were no significant changes in the percentages of fish within each age class. This conclusion was validated by the constant survival rate estimates, for age groups 4-8 and older, over the three year period.

Due to ageing error associated with scale analysis and the small sample sizes of older fish, survival rates for the oldest age classes in the population are not known, and survival rates for age classes over age 6 or 7 are probably biased due to accumulation of erroneously aged older fish. This was apparent when looking at the age class distribution and survival rates of the estimated otolith age sample. Because catch curve analysis utilizes proportions of the sample in each age category, when there are few older fish in the sample, a low survivability is indicated.

Fish were assumed to be partially recruited into the sport fishery beginning at age 4, since most age 3 fish were found in dense cover (e.g., log jams) that is not usually targeted by the sport fishery. However, age 4 and older fish were also associated with this dense cover type. Therefore, recruitment into the sport fishery may range over several age classes and may have biased the catch curve analysis. Hook and line sampling may also have selected for larger, older fish.

The discrepancies between the numbers of younger age fish expected and observed in our sample may be the result of ageing error, later or variable recruitment age or selectivity of sampling gear. Therefore, the assumption of equal year class strength cannot be tested.

Kwain (1981) reported a total mortality rate of 41% for Stokely Creek, Ontario, Canada, rainbow trout with a 3.8% first year recapture rate of tagged fish. The recapture rate of 1985 fish tagged on the Kanektok River was 9.7% after one year at large and 2.9% after two years. The recapture rate of 1986 tagged fish was 10.1% after one year.

The assumption of population equilibrium is impossible to test at this time. Rainbow trout mortality rates are based on only the sport caught population and recruitment data are not available. There is probably some compensation between fishing and natural mortality rates (especially for older fish) so that all fishing mortality increases would not be additive. Based on catch curve analysis, fish aged 8 and older experience an estimated total mortality of 70% to 80% at the present time. This is probably a result of a combination of effects (e.g., spawning stress and fishing mortality). If no compensation mechanism exists, these age classes may be sensitive to even small increases in fishing pressure.

Population Estimates

Population estimates of stream dwelling fishes are difficult due to the inherent nature of the system. Many assumptions must be made and in two stage mark-recapture experiments there is no way to test these assumptions (Brownie et al. 1985). It is generally believed that the Petersen method underestimates the true population level, especially with small sample sizes (Everhart and Youngs 1981).

Due to the long sampling sessions employed in these estimates, geographic (migration) and demographic (recruitment, mortality) closure cannot be assured. Although some in-river fish movement was observed through tag returns, it is not believed to be widespread enough to seriously bias these results. Seventy-six percent of the 79 tag returns including location data were recaptured within 1.6 km of their original tagging location. Thirty percent of the tag returns did not indicate location of capture. One fish captured by a Quinhagak resident 4 April 1987 at km 24 had originally been tagged at km 46 on 18 July 1986, the only evidence of downstream migration. As mortality and growth rates appear to be low, the assumption of demographic closure may not be severely violated.

The assumption of equal vulnerability to capture of marked and unmarked fish cannot be adequately addressed. Estimates of probability of capture were

too low (especially in the 1985 Petersen estimate) to justify the assumption. Behavioral observations of lure shy fish, the presence of environmental factors affecting behavior (spawning salmon, anadromous char, water temperature) and basic heterogeneity of individuals are all factors influencing the catchability of rainbow trout. The length of the sampling session may have negated these behavioral and environmental effects on capture probability. There was no evidence of tag loss during the study, however, we are unable to verify tag retention.

Fessler and Lichens (1978) estimated from 69-190 age 2 and older rainbow trout per km in the Deschutes River in Oregon using a drift boat electroshocker. Zubik and Fraley (1988) estimated the density of age 3 and older Flathead River, Idaho cutthroat trout ($\underline{O}$. clarki) at 452 and 527 fish per km by angling and snorkeling. Population estimates in 1986 and 1987 for a 16 km section of the Kenai River, Alaska, produced point estimates of 228 and 280 rainbow trout per km (R. Lafferty, University of Alaska, personal communication). The Kenai River estimates were based on hook and line sampling in 1986 and electrofishing sampling in 1987, and fish greater than 150 mm were considered the catchable population. Our estimates of catchable size rainbow trout (536 and 631 fish per km) include fish over 300 mm, and are greater than the Kenai, Flathead and the Deschutes River estimates. The amount of habitat per km contributed to the high density of rainbow trout in the Kanektok River. The river is braided and more habitat per km is available for rainbow trout residence.

Increased sample size of marked and recaptured rainbow trout in 1986 resulted in tighter confidence intervals, improved measures of precision, a lesser degree of negative bias and an improved estimate of capture probability. Considering the individual biases of the assumptions, the overall population estimate of rainbow trout in the study area is likely to be low.

Effort, Catch and Harvest Estimates

Total fishing effort (angler days) in the study area decreased approximately 6% over the creel survey study period (1986-1987), although guided angler use increased roughly 9%. The moratorium on the number of client use days by commercial guides has prevented much fluctuation in effort levels by this group. Unguided angler effort increased steadily from 1984 (an estimated 272 angler days) to 1986 (501 angler days). In 1987, unguided angler effort dropped 44% (282 angler days) and rebounded to an estimated 432 angler days in 1988 (M. Lisac, U.S. Fish and Wildlife Service, personal communication). The factors contributing to the fluctuation in unguided angler effort are unknown.

For unguided float anglers, catch rate increased approximately 8% from 2.2 to 2.4 rainbow trout per angler day during 1986-1987. Unguided float anglers were the only group showing an increase in fishing success in 1987, although a higher success rate was anticipated as environmental conditions were excellent for fishing (consistently low, clear water levels). The previous year was considered average by river users with higher levels of precipitation, river flow, and turbidity.

Catch rates declined for guided motor boat anglers in 1987. This decline could have been because motor boat anglers targeted more on salmon in 1987 or could indicate a possible weakness in the technique used to expand catch information in 1986.

Guided float anglers were the most successful group sampled both years. This may be a result of their targeting rainbow trout in the study area or more complete reporting of catch data. Float anglers may spend a greater amount of actual fishing time per day compared to motor boat anglers who may spend more time traveling between fishing locations.

Rainbow trout catch per unit effort varied throughout the season reflecting changing environmental conditions and probability of capture. These factors included: water clarity and depth, food availability, frequency of capture (of individual fish), presence of other species (salmon and anadromous char), and user group affiliation (guided versus unguided).

Department estimates of rainbow trout sport catch and harvest in the lower Kanektok River tend to be low as Department creel surveys emphasize chinook and coho salmon data collection and rainbow trout data are collected incidentally. These surveys probably do not indicate the true seasonal level of effort, catch, and harvest for rainbow trout in this river section.

Few fish are harvested in the upper river, as voluntary catch and release of rainbow trout is practiced and there are limited means to preserve fishes. A higher fish retention rate was reported in the lower river creel survey, especially for salmon (Minard 1987).

Since the rainbow trout sport harvest appears to be negligible, the more pertinent question is: What are the short and long term effects of hooking and handling stress upon mortality rates? The basic model described here indicates that present effort levels have little effect on total fish mortality. A low harvest rate and voluntary catch and release policy have kept fishing mortality levels low. However, not accounting for recaptures, one in every three fish was captured in 1986, and the full effect of this high harvest potential and catch rate has not yet been determined.

Fishing mortality studies indicate that many factors affect hooking mortality including: size of fish, hook size, hook location in the fish, angling technique, and water temperature. Most conclude that artificial flies and lures produce mortality rates of under 10% (Dotson 1982, Horak and Klein 1967, Wydoski 1977). Horton and Wilson-Jacobs (1985) reviewed hooking mortality data from Canada and Washington and recommended using a 10% hooking mortality level for steelhead trout management considerations. A 10% delayed mortality due to hooking and handling stress may be conservative for Kanektok River rainbow trout as tag return data suggests fish may be recaptured several times throughout the season.

Estimates of sport fishing mortality generated from 1986 creel survey data and the population estimate indicate a loss rate of approximately 4% per year of the rainbow trout in the study area. Creel data from a ten year study of Sagehen Creek, California, reports that anglers annually removed 33% of trout over 99 mm in length, but natural recruitment replaced the loss (Gard and Seegrist 1972). The lack of estimated spawner numbers, spawning

frequency, spawner percentages by age group and fecundity data prevents recruitment estimates at this time.

Sport fishing mortality rates varied among user groups between the two years. Based on catch statistics, guided float anglers have the highest estimated total fishing mortality, a result of their overall higher catch rate. Guided motor boat anglers showed a lower fishing mortality in 1987, also a result of their lower catch rate. The high fishing mortality rate for unguided float anglers in 1987 may be biased, as this estimate was highly influenced by one group with an unusually high harvest rate, and only 50% of the unguided float anglers were interviewed.

The annual variability and accuracy of subsistence harvest data are of greatest concern. Approximately 2,300 rainbow trout were harvested in 1988-1989, which equates to an exploitation rate of 11%. Therefore, sport and subsistence fishers annually harvest about 15% of the catchable size rainbow trout in the Kanektok River. Little information on acceptable exploitation rates for resident Alaska rainbow trout is available. Lafferty (1989) stated that in the Kenai River, Alaska, a stable population could be maintained with exploitation rates up to 14%; exploitation rates greater than 14% could affect the population age structure. A harvest rate of 15% in the Kanektok River, coupled with annual survival rates of 20-30% for older age classes, could cause these older age classes to be overharvested. Older fish may be caught several times by sport anglers, which increases the probability of death due to hooking mortality. In addition, large fish are more likely to be retained by sport anglers for mounting as a trophy. The subsistence fishery may also harvest a disproportionate number of larger fish because of gear selectivity. Until long term population trends and harvests are evaluated, a cautious approach to management should be followed.

Conclusions and Recommendations

Length frequency distribution and age class composition data do not indicate any adverse effects of sport fishing pressure during the study period. Angler harvest is not limiting the population as sport fishing does not occur in any significant levels during spawning, and voluntary catch and release practice provide a high level of protection for rainbow trout at this time. To insure present catch levels do not increase dramatically, we recommend continued monitoring of the sport fishery through Special Use Permits and public use surveys. As a condition for receiving a Special Use Permit, the Togiak National Wildlife Refuge should require mandatory reporting of catch, effort, and harvest on a monthly basis.

Although it appears as if larger increases in angler effort would produce small increases in total mortality, we recommend conservative management of this resource. Hooking mortality is a major concern, as our data indicate that one in three fish were captured and handled at least once during 1986. Additional studies are necessary to determine the effects of multiple recaptures and refine fishing mortality estimates. Also, natural fluctuations in population size necessitate additional population estimates to determine the range of exploitation rates occurring in the fishery.

A conservative approach will maintain the existing Kanektok River rainbow trout population. Because the population is not characterized by many

large trout (> 600 mm), designation of the Kanektok River as a 'Trophy Trout' stream, and the associated management practices (i.e., mandatory catch and release, size or slot limits, gear limitations, area or seasonal closures) are not recommended at this time.

ACKNOWLEDGEMENTS

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Appendix A.--Catch and harvest statistics for other species of interest, Kanektok River, Alaska, 1986-1987.

Year	Group[a]	Fish Species						
		Chinook Salmon	Coho Salmon	Sockeye Salmon	Chum Salmon	Pink Salmon	Dolly Varden	Arctic Grayling
1986	GMB	74/ 9	3,928/ 76	126/ 7	262/ 9	917/ 9	7,386/116	909/60
	GF	93/ 0	7,099/ 42	711/12	702/ 0	3,019/ 3	5,601/ 31	1,871/ 0
	UGF[b]	241/ 0	2,680/ 66	36/ 8	77/ 2	267/ 0	3,251/ 16	947/ 2
	Lower	1,935/835	10,337/1,496	481/34	5,222/305	4,880/ 97	4,292/493	0
	Total	2,343/844	24,044/1,680	1,354/61	6,263/316	9,063/109	20,530/656	3,727/62
	% Harvest	36%	7%	5%	5%	1%	3%	2%
1987	GMB	300/ 73	706/ 106	365/62	532/ 12	3/ 1	5,171/427	769/14
	GF	274/ 6	411/ 5	558/ 1	469/ 1	70/ 0	6,139/ 43	1,438/30
	UGF	2/ 0	52/ 6	0	0	0	364/ 9	75/ 0
	Lower	1,903/375	-	214/18	1,090/112	-	149/ 20	-
	Total	2,479/454	1,169/ 117	1,137/81	2,091/125	73/ 1	11,823/499	2,282/44
	% Harvest	18%	10%	7%	6%	1%	4%	2%

a   GMB = guided motor boat anglers
    GF = guided float anglers
    UGF = unguided float anglers
b   Lower study area is km 32 to mouth of river in 1986 and km 20 to mouth of river in 1987 (Minard 1987).

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